A 90 GHz, Corrugated, Compact Packing, Focal Plane Layout, Platelet Antenna Array

Briony Horgan, Physics, Oregon State University

NNIN REU Site: Nanotech at UCSB, University of California Santa Barbara
Principal Investigator: Dr. Philip Lubin, Experimental Cosmology, University of California Santa Barbara
Mentor: Dr. Miikka Kangas, Experimental Cosmology, University of California Santa Barbara
Contact: briony@orst.edu, lubin@cfi.ucsb.edu

Abstract:

Corrugated feed horns channel light from free space into waveguides while reducing noise and interference; however, they are expensive to fabricate using current methods. The platelet fabrication methods presented in this paper are straightforward and inexpensive, allowing efficient development of large arrays of corrugated horns. The focal-plane horn array improves upon our previous scalar designs by allowing the array to focus on one point, such as the primary mirror in a telescope.

Unfortunately, tests conducted on the compact-packing array suggest that reflections within the horn skew the beam pattern results. We have concluded that curving the horn near the aperture interferes with optimal operation.

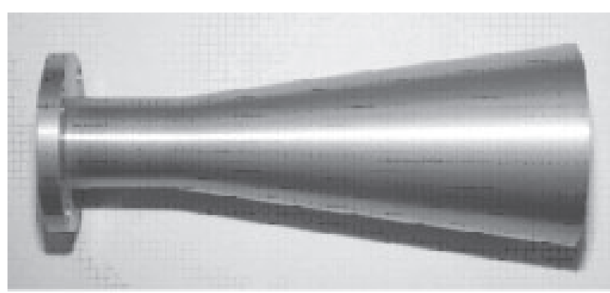
Introduction:

One of the broadest goals of astrophysics is to gain an understanding of the evolution of the universe. General relativity allows for several different evolutionary models, all differing by what values they assign unknown cosmological constants. By examining disturbances in remnant thermal radiation from the big bang—known as the cosmic microwave background (CMB)—astrophysicists can describe the distribution and composition of the early universe, which in turn helps to determine the most accurate model.

The Lubin Experimental Cosmology group employs arrays of thermally sensitive detectors in their satellite and balloon-borne CMB telescopes. The impedance mismatch between free space and the inside of the detector waveguide can cause reflections at the aperture. To overcome this effect, a type of waveguide known as a horn is used. As shown in Figure 1a, a horn resembles a funnel, and acts in a similar way. By gradually increasing the impedance of the waveguide from that of free space, the horn "funnels" the incoming light into the waveguide.

Ideal metal is infinitely conducting and does not interact with electromagnetic waves. As the metal in the walls of the waveguide is not ideal, it will produce reflections. Cutting grooves into the wall of the horn with a depth of 1/4 of a wavelength counteracts this effect. When the component of a wave that is perpendicular to the surface reflects back, it will destructively interfere with itself at the entrance of the groove, effectively eliminating all light contacting the surface. This method also allows the horn to be "tuned" to a specific frequency. Unfortunately, the grooves make molding the horns difficult, which is why we have pursued the development of platelet arrays [1].

Previously, we have tested platelet arrays composed of straight, unfocused horns. Focusing the array on the "source," as shown in Figure 1b, improves the array's resolution. Although straight and focused horns would be optimal, this would not allow us to use the same detector array as for the unfocused horn array. Our solution is to curve the horns so that the aperture is directly over the exit waveguide, as shown in Figure 2a.



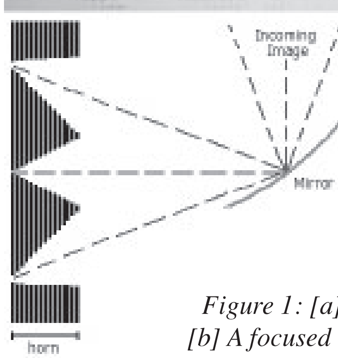


Figure 1: [a] An electroformed horn.
[b] A focused horn array in a telescope.

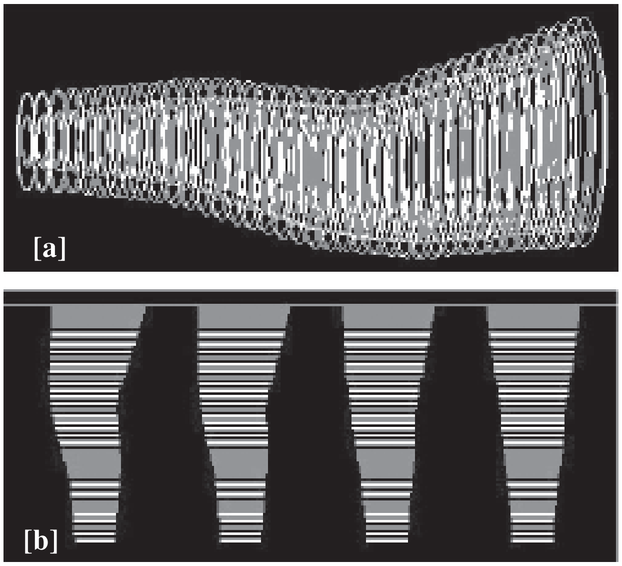


Figure 2: [a] A compact-packing horn.
[b] A 4-pixel horn array.

Procedure:

We designed our horn arrays using the LISP scripting language and AutoCAD. We can now generate designs for straight, focused, and curved arrays at any size and frequency, quickly and easily.

For our prototype, we chose to build a small, 90 GHz, 4-horn array, with aperture tilts of 0°, 5°, 10°, and 15° (Figure 2b). Made entirely with brass stock and brass shim stock, the array consisted of 75 plates ranging from 3 to 40 mils in thickness. Although the 0.5-inch base plate with waveguide sockets was fabricated using machine shop quality mills, the array plates themselves were machined using MasterCAM and a MaxNC tabletop CNC mill.

After aligning and assembling the plates, the array was exposed to a Gaussian, W-band source that spanned over 40° at full-width, half-max. The array was mounted on a stepper motor, and the output of each horn was recorded every 40 arcminutes between $^{-}60°$ and $^{+}60°$ in both azimuth and elevation. After passing the co-polar and cross-polar outputs for both the E and H-planes through multiple optical amplifiers, a whisker diode and a lock-in amplifier, we produced the intensity graph shown in Figure 3b using IDL data processing software and in-house algorithms.

Results and Conclusions:

We have previously shown that using the scalar horn results in a gain of 20 dB and side lobes attenuated from the main lobe by at least 22 dB, which satisfies requirements for use in CMB observations [2]. Tests conducted on the curved prototype indicate that it has a high gain, but lacks the resolution of the scalar horns because of multiple main lobes and unwanted cross-polar signal amplification.

Figure 3a shows an intensity map for the co-polar source-detector orientation for our straight horn prototype. Figure 3b shows the same map, albeit less finely tuned, for our curved horn prototype with maximum slant (15°). The central lobe is as expected; however, the secondary lobe on the right should not be present. We have attributed its presence to internal reflections within the curved, outer section of the horn.

Future Work:

The group is currently developing a horn design that should eliminate both the problem of the internal reflection inside the curved horn and the need for the aperture of the horn to be directly over the waveguide. Instead of curving the horn near the aperture, the first 75 plates are linearly slanted. To align the aperture, another 75 plates will be added with the corrugated waveguide slanting in the opposite direction.

Acknowledgments:

I would like to thank Dr. Miikka Kangas, Dr. Phil Lubin, the Lubin research group, and the UCSB Physics Machine Shop staff for all their support and assistance. I would also like to thank our sponsors: NNIN, NSF, California Space Grant, and California Space Institute.

References:

[1] R.W. Haas, et al., "A submillimeter wave platelet horn array: fabrication and performance," 5th Int. Conf. on Space and Terahertz Tech., 1994, pp.674-681.

[2] M.M. Kangas, et al., "A Modular 90-GHz High-Gain Scalar Corrugated Platelet Antenna Array," IEEE Trans. Antennas Propagat., in progress.

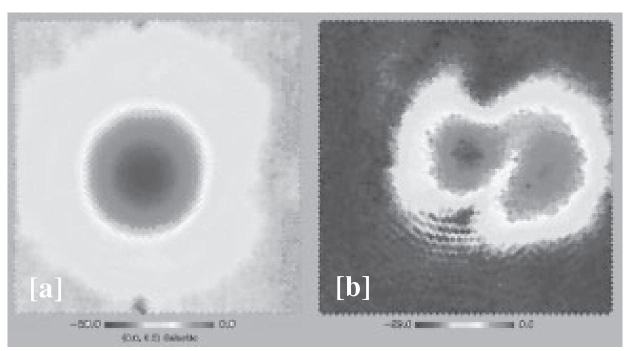


Figure 3: Co-polar intensity-dB plots for
[a] straight and [b] 15°-slant compact-packing horns.